An OPAD System to Fly on DC–XA

Marshall Clinton Patrick/EB22
205–544–3836
E-mail: clint.patrick@msfc.nasa.gov

For several years, MSFC engineers have been collaborating with other NASA centers, Government agencies, universities, and businesses in attempts to apply spectrometric analysis to the monitoring and diagnosis of rocket engine health. The Space Shuttle Main Engine Technology Test-Bed (SSME TTB) in Marshall's west test area has been home during this time to several incarnations of sensor systems designed to identify traces of metals in the exhaust. These efforts have met with satisfying and encouraging results. Instruments for this purpose are grouped together under the technology entitled optical plume anomaly detection (OPAD).

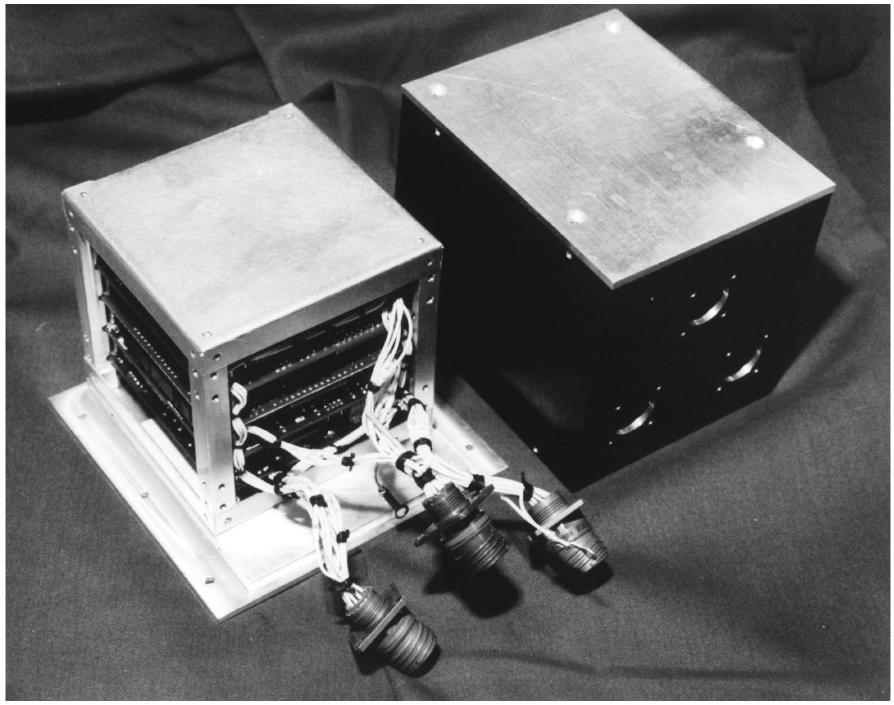

Figure 93.—DC–XA OPAD control computer assembly.

While advances were being made in the technology required to actually accomplish optical plume analysis, the question was being asked: "Will it fly?" For this reason, the opportunity to put a test instrument aboard DC–XA was met enthusiastically. The objectives of this endeavor were fairly basic: First, to fly a working version of an OPAD instrument; second, to do it using inexpensive commercial off-the-shelf (COTS) hardware where possible; and third, to collect useable data.

A decisive first step involved choosing a hardware platform upon which to build. Although it was relatively young, the PC/104 format was promising as a miniature computer standard with a rapidly growing vendor base. This format restricts computer cards to approximately the dimensions of a 3-in floppy diskette, with 0.6 in separating cards in a stack. The potential thus existed for a control computer box measuring no more than 6 in in any one dimension.

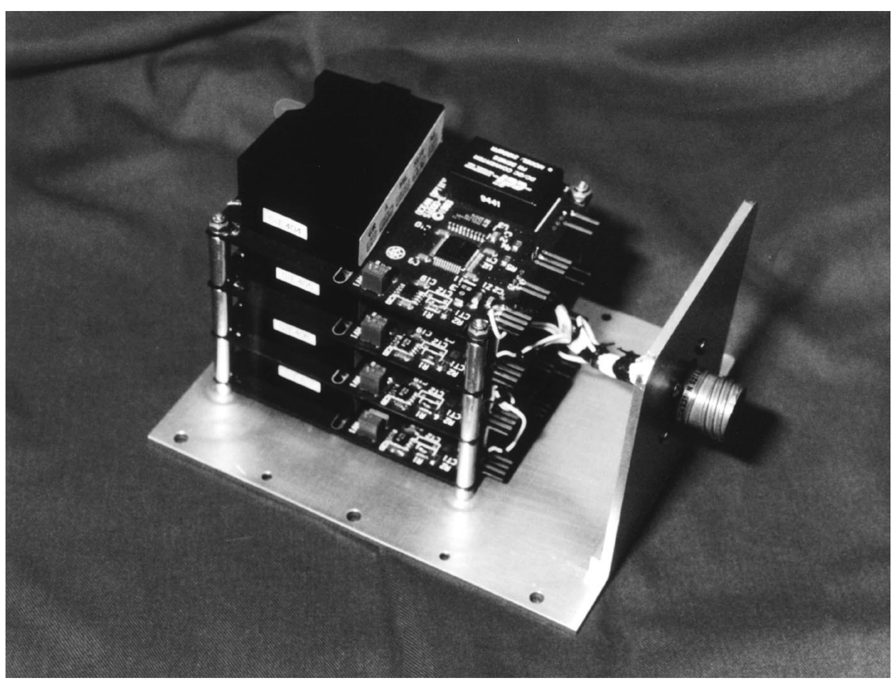

Figure 94.—DC–XA OPAD spectrometers assembly.

No single PC/104 vendor had all of the component cards required to assemble a complete system. For this reason, the central processing unit (CPU) card and analog-to-digital converter card were purchased from Real Time Devices (RTD), the 16-megabyte flash disk card came from M-Systems, the enhanced serial communications card (ESCC) from WinSystems, and the dc-to-dc power supply from Tri-M. The ESCC was capable of extended temperature range operation (about –40 to +80 C), while the remaining boards were screened for this capability at an extra charge. Additionally, a standard temperature range video card was purchased from RTD for use only during system development.

The individual cards were modified in that on-board jumpers were soldered in place, all connections to the outside world were made using soldered wire rather than connectors, wire bundles and socketed chips were tied down with lacing cord, and the clock battery was sandwiched between cards using RTV. All of the flight cards were stacked with stainless steel standoffs and installed in a custom enclosure from Parvus Corporation. Cost of the computer cards was approximately $4,000, and the custom enclosure was an additional $1,000.

Software was developed in Borland C++ on a separate desktop computer, then ported to the control computer using LapLink. The compiled executable was targeted to the DOS environment. Modifications of the executable at the launch site, and downloading of test data in some instances, were accomplished on a ground connection to the CPU card's built-in serial port through a vehicle umbilical; unfortunately, this link was limited to a rate of 9,600 baud, a relative snail's pace by current standards.

The spectrometer units were housed apart from the control computer. Ocean Optics supplied four ruggedized miniature spectrometers, one per engine, which were stacked using stainless steel standoffs. Each spectrometer unit was different from the standard COTS unit only in that the optional lens assembly in the optics section was mounted in epoxy for stability. Cost of the four-unit stack was approximately $4,000. It was mounted in a custom enclosure produced in-house at MSFC.

Light from the engine plumes at the base of the vehicle had to be collected and presented to the spectrometers in the avionics rack near the top of the vehicle. For this purpose, each unit had a 40-ft quartz optical fiber which ran to a miniature telescope assembly near one of the engine nozzles. Fibers were purchased in custom lengths from Ocean Optics, for about $400 each. Arnold Engineering Development Center designed and produced the telescopes in-house.

Before each test of an OPAD system, a series of calibrations must be performed to ensure that test data subsequently collected is meaningful. Such a series includes scans of the optical field in ambient light, followed by scans with a calibrated wavelength source, then a final scan with a calibrated intensity source. The first of these is subtracted to help negate the effects of ambient light and electronic "dark current" noise. Wavelength data allows correlation of individual data points to specific wavelengths. Finally, intensity calibration helps to determine the relationship between an intensity count for a given data point and the actual optical intensity received at the engine telescope.

Static firings preceding the first flight of the DC–XA allowed attempts to finalize procedures and verify the system, since installation in the vehicle was the first time it was completely assembled. While data were collected before and during these firings, procedural and hardware problems prevented successful collection of both valid calibrations and test data during any given test. On the other hand, it was very encouraging that the electronics operated at all under the extreme conditions of the launch site during these tests.

The experiment hardware continued to operate during four subsequent flights. However, telemetry downlink failure during the first flight prevented collection of any flight data whatsoever. Then, the system failed to receive its startup signal from the vehicle computer on the second flight. Data was successfully collected during the third flight, but the calibration data was found to be invalid. Finally, the fourth flight yielded success. Engine ignition and shutdown

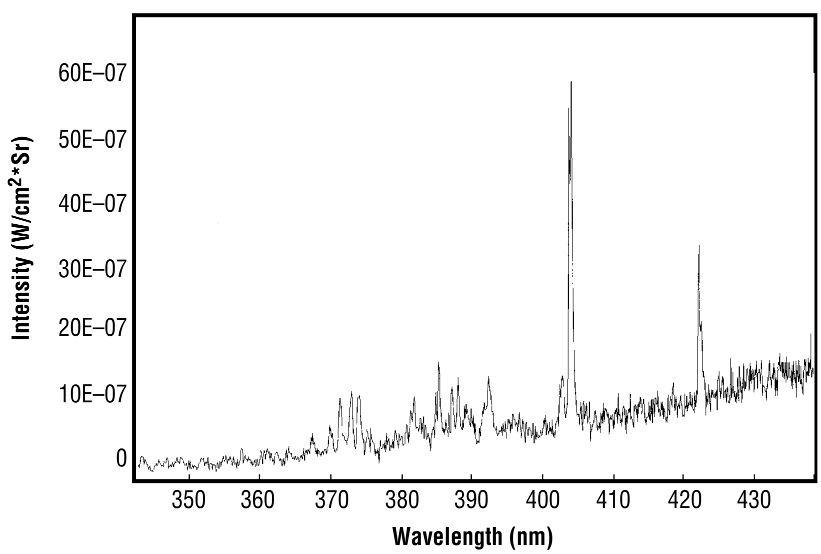

Figure 95.—DC–XA engine two emission spectrum at T+3 sec (Flight 4).

were detected in this data, as evidenced by spectral activity. Figure 95 shows emission activity at engine start plus 3 sec.

Flight four was unexpectedly the last flight of the DC–XA. Upon landing, the vehicle failed to deploy one of four landing legs, fell over, exploded and burned. Amazingly, the OPAD boxes were not consumed by the oxygen fire or the subsequent few hours of exposure to the burning vehicle. In fact, the control computer is still operational, with the exception of its serial ground communication link; its survival can be attributed mostly to a rugged enclosure. The spectrometers, housed in a much lighter and poorly sealed enclosure, did not fare as well though located mere inches from the control computer. All of the vendors have expressed interest in examining their components in hopes of learning from this incident.

Technically, all of the project's basic objectives were met. An OPAD system built with COTS hardware was flown to several thousand feet, and valid data were collected. Even though only one set of data from one engine for one flight was the immediate final product, a wealth of information was gleaned to benefit future generations of rocket-propelled vehicles. The exercise itself emphatically pointed out the necessity for rethinking aspects of ground-based OPAD hardware in order to adapt and harden it for vehicle operations and flight. Calibration procedures must be reworked to make them more compatible with the launch pad environment. The fact that flight conditions include the use of cryogenics in the vicinity of the OPAD instruments presents it own set of complications. In addition, problems experienced with serial ground communication pointed out that remote computing, as it relates to the requirements of this type project, is a very young technology.

Sponsor: Reusable Launch Vehicle Program Office

Industry Involvement: Real Time Devices, Inc.; M-Systems Inc.; Parvus Corporation; Tri-M Systems; WinSystems, Inc.; Ocean Optics, Inc.

Other Involvement: USAF/Arnold Engineering Development Center

Biographical Sketch: Marshall Clinton Patrick is an electronics engineer in the Instrumentation Branch at MSFC. He specializes in electronics design, data communication, and small systems integration. Patrick earned his electronics and computer engineering degree from the University of Alabama in Huntsville in 1986 and has worked for NASA for 15 years.